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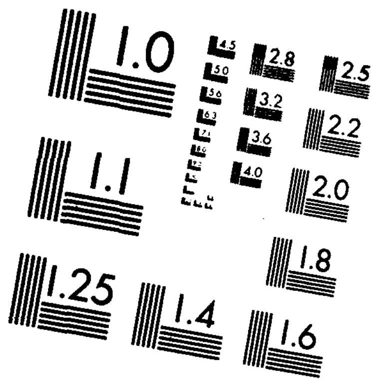

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EMC ANALYSIS of the MAS-FEB

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EMC ANALYSIS of the MAS-FEB

1. Scope

This document is to establish the format and methods by which EMC Control is achieved for the FEB. It is not a detailed control design, but discusses the methods and philosophy by which such a design will be achieved.

2. Relevant Documents

2.1 RS-MAS-DS-001, MAS ELECTROMAGNETIC COMPATIBILITY SPECIFICATION

2.2 MAS EMC DESIGN CONTROL PLAN AND TEST PLAN. Issue A, August, 1985, prepared by Dornier Systems for DFVLR

2.3 GEVS-STS, GENERAL ENVIRONMENTAL VERIFICATION SPECIFICATION FOR STS PAYLOADS, SUBSYSTEMS, AND COMPONENTS, GSFC, September, 1984

2.4 MIL-STD-461A ELECTROMAGNETIC INTERFERENCE CHARACTERISTICS REQUIREMENTS FOR EQUIPMENT

2.5 MIL-STD-462 ELECTROMAGNETIC INTERFERENCE CHARACTERISTICS, MEASUREMENTS OF

2.6 ESA PSS-01-301

3. EMC Control Philosophy

Much painful experience in the field has taught us the importance of EMC control to the success of experiments. In addition, the Space Shuttle has definite EMC specifications which must be met (documents 2.2, 2.3). However, it is well known that an optimum solution cannot be achieved by confining EMC design to solely the box or sub-box level.

3.1 Internal FEB EMC Control: Sub-Box Level

This problem at the sub-box level will be handled internally by NRL-PSU but with full information to other organizations. Extremely tight shielding and filtering at the sub-box level is very often wasteful and, because of additional weight and complexity, may ultimately be detrimental to the success of the experiment. It is our plan, however, that each sub-box will be a potentially excellent RF shielding enclosure.

3.2 External FEB EMC Control

3.2.1 Radiated EMC Control, Shielding

In this area we can easily afford to be quite conservative in design. The FEB box will be an extremely "tight" RF enclosure, using thick metallic walls and "state-of-the-art" gasketing of all seams.

The relatively thick (2.5 mm) outer walls of the FEB provide excellent shielding. The overall shielding effectiveness of a metallic wall arises from both reflection of the plane wave from the front surface, absorption of the wave during transmission through the

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metallic wall, and additional reflection of the exiting wave at the back surface of the wall.

$$SE = Reflection + absorption + B$$

The following calculations will show that at the lowest frequency of interest (14 kHz) the absorption is much greater than 10 dB so that the additional reflection term, B, can be neglected.

The absorption term can be calculated by

$$A_{dB} = 3.338\ E\text{-}03 * t * (u * f * \epsilon)^{1/2}$$

$$= 1.314 * (f * u_r * \sigma_r)^{1/2} * d$$

where d is the thickness in cm and for Aluminum $u_r = 1$ and $\sigma_r = 0.61$

Thus $A_{dB} = 1.314 * (0.61)^{1/2} * 0.25 * (f)^{1/2} = 0.256 * (f)^{1/2}$

The reflection of incoming plane waves at the metal surface can be calculated by

$$R_p = 168 - 10 \log_{10} (f * u_r / \sigma_r)$$

$$= 168 - 10 \log_{10} (f/0.61)$$

$$= 165.9 - 10 \log_{10} (f)$$

The following partial table of the net shielding effectiveness shows the large numbers which result from the thick wall of the FEB.

f	R_p	A_{dB}	SE
14 kHz	124.4	30.3	154.7
100 KHz	115.9	80.9	196.7
1 MHz	105.9	256	361.8
10 MHz	95.9	809	.
100 MHz	85.9	.	.
1 GHz	75.9	.	.
2 GHz	72.8	.	.
10 GHz	65.9	.	.
13 GHz	64.7	.	.
15 GHz	64.1	.	.

The shielding effectiveness is greater than 200 dB at 150 kHz. At these levels, the tightness of the seams and connector leakages become the primary leakage path. All seams will be gasketed with a silver-plated, aluminum filled, elastomer gasket. The separate metal enclosures ("doghouses") which enclose the data and power connectors are similarly sealed with an elastomer gasket.

Venting of the FEB to the cargo bay is required. The internal volume of the FEB and the maximum allowed pressure differential determines the number and cross-section of the vent holes. These vent holes are arranged to enter the FEB through a thick-ribbed portion of

the end wall so that each hole operates as a beyond cutoff waveguide filter. For the 0.25 inch diameter holes, the length of the hole is sufficient to produce greater than 90 dB attenuation at 15 GHz

3.2.2 Conducted EMC Control

The only penetrations of the FEB enclosure are the five microwave inputs from the RXE, the +28v +/- 2 % power and ground from the PEB, and the 12 data and ground lines to the DEB. They will be treated as follows.

3.2.2.1 Microwave Inputs: These will go through semi-rigid coaxial cable directly to a well-shielded "front end," with additional filtering of the associated wiring as necessary to minimize internal RF pickup on these lines. There is sufficient space for the addition of extraordinary measures such as additional selective filters if this proves necessary.

3.2.2.2 Power Input: The power input connector will be surrounded by an RF tight "doghouse" containing PI-section bulkhead EMI filters (Spectrum Control 51-719-021) which meet the relevant MIL specifications (MIL-F-15733). These have good attenuation: 14dB at 10 MHz 50 dB at 100 MHz and 70 dB at 1 GHz (all specified in a 50-ohm system.) The capacitance between the conditioned +28 and 0 volt leads to the box due to the EMI filters is required to be less than 0.05 microfarad. In addition, the derating factor for RFI filters is 50%. Most RFI filters are rated for 10 A. Since the FEB is expected to draw 6.7 A, multiple parallel RFI feedthroughs must be used. Both the +28 and the ground lines from the power connector are passed through RFI feedthroughs into the interior of the FEB. Five connector pins are used for each. Three of these connect to one RFI filter, the remaining two connect to the other (Figure One). A similar pair of RFI filters is used for the ground return. When wires are used in parallel to handle a large current load, the individual current rating of each wire must be additionally derated (Ref. 2.6).

$$Ibw = Isw * (29 - N)/28 = Isw * (29-3)/28 = Isw * 0.93$$

Thus, the orginal 10 A rating of each RFI filter is derated to

$$10 * 0.5 * 0.93 = 4.65 \text{ Amp}.$$

The two parallel RFI filters can thus easily carry the required 6.7 Amp to the FEB power supply.

The voltage rating of the above RFI filters is 200 Volts. Derating by 50 % results in 100 volts compared to the actual voltage of 28 volts.

The capacitance of such RFI feedthroughs is usually specified

by the manufacturer as a minimum capacitance, rather than a maximum capacitance as required in this application. The above units have a nonomial capacitance of .0055 microfarad each. The capacitance of each flight unit is individually measured to verify an actual capacitance of not more than .01 microfarad each. The total of four RFI filter capacitors are thus guaranteed to not produce more than 0.04 microfarad between the secondary power line and the FEB case.

All connectors are indexed and keyed so that during assembly and checkout there can be no accidental power supply reversal.

3.2.2.3 Data lines: A similar "doghouse" will enclose the data connector and PI-section EMI filters similar to those we have frequently used in rocket payloads (Oxley FLTM/P/680) will be placed in all data and "ground" lines. These units have approximately 680 pf. Individual capacitance measurement is used to verify a maximum capacitance of 1000 pf to ground for each data line. They have an insertion loss of 65 dB at 100 MHz and 70 dB at 1 GHz in a 50 ohm system.

Using the maximum capacitance value of 1000 pf and a source resistance of 39 ohms in the line driver, each data line will be lowpass filtered with a time constant of 0.039 microsecond. From the overall data rate of 312.5 Kbit/sec the bit time can be found to be 3.2 microsecond. Thus little pulse degradation is expected.

Digital circuit guard band analysis of these data transmitters and receivers follows the standard manufacturer data sheet specifications for the matched line drivers and receivers.

3.2.2.4 Temperature monitor: An YST 44006 thermistor is contained within the FEBC (data) doghouse and is attached to the outside sidewall of the FEB. The electrical connections of this thermistor are to pins F (thermistor), G (thermistor return), and H (thermistor shield).

4. Frequency Plan

4.1 Frequencies generated locally

The following local oscillator signals are generated by six programable synthesizers:

5493.430 MHz for temperature
1980.091 MHz for watervapor
3047.820 MHz for ozone
3646.029 MHz for pressure range 1
3075 480 MHz for pressure range 2
952.000 Mhz for chlormonoxyd

Each of these is tunable +/- 10 MHz.

In addition several fixed crystal oscillators are used with the following frequencies:

200.000 MHz
45.000 MHz.

All of these are used to drive mixers which have LO-RF isolations greater than 20 dB. In addition, greater than 20 dB reverse isolation is expected in the line amplifiers which precede the mixers.

The computer has a 5 MHz crystal controlled clock. CMOS logic is used by the computer so that waveform rise and fall times are well behaved.

4.2 Frequencies utilized locally

The following frequencies are used from the five RF input signal lines:

5043.430 - 5443.430 MHz
2030.091 - 2430.091 MHz
3097.820 - 3497.820 MHz
3196.029 - 3596.029 MHz
2625.480 - 3025.480 MHz
1002.000 - 1402.000 MHz

Drawings 2036-131 623.1 and 2036-131 520 show the nominal frequencies and power levels of the RF distribution and IF distribution, respectively. Drawings 2036-131 221 and 2036-131 231 show the filter electronics. The various filter modules operate from 232 MHz to 270 MHz, 31 MHz to 69 MHz, and 3.2 MHz to 7.0 MHz. Drawing 2036-131 420 shows the FEB computer.

5. Bonding, and Grounding

5.1 Bonding

All machined aluminum assemblies and housing will be chemically treated with a chromate coating to insure a continuous ground system. The large mechanical components of the outer box and bottom mounting plate and smaller inner boxes will be treated with Iridite 14-2. Internal bonding is provided by the thick (3/8 inch) aluminum base plate which is the common internal ground for the entire FEB, due to the RF grounds of the semirigid cable that interconnect the RF modules. The synthesizers and input amplifiers mount on a sub-plate which then mounts directly to the bottom plate. The filters are metal enclosed and mount on various printed circuit boards, that in turn are enclosed in a metal case. These filter assembly cases mount directly to the FEB bottom plate. The mating surface between the bottom plate and the connector plate end wall is 0.008 m^2. External bonding is performed by the 15 mm dia contact area of the grounding/bonding stud. The net area is 0.000148 m^2. Each RF input connector is of the SMA type and provides a bonding area of 0.0000445 m^2. The power connector, 3J06, has a bonding area of 0.000422 m^2 and the data connector, 3J07, has a bonding area of .000452 m^2 (Drawing 2036-131 321).

5.2 Grounding

The 5 mm diameter grounding stud is mounted on the connector plate end wall for connection to the ground strap which comes from the Shuttle (CPSS). This provides the overall FEB to Shuttle ground, since the thermal filler between the FEB bottom plate and the cold plate is electrically insulating. The incoming secondary power ground is passed directly through a pair of EMI filters and to the DC-DC converter (twisted pairs with the hot lead). Data line grounds are similarly passed through the EMI feedthroughs in the "doghouse" Internal power supply values (+ 15 v, -15 v, and +5 v) and power supply grounds will be distributed through a connector bay mounted over the doghouses. This power distribution bridge has connectors for disconnecting the cables from the RFI filters at the back of the power and signal doghouses. In this way isolation of the incomming grounds can be verified for the creation of the "single-point" ground which occurs on the power supply bridge (Drawing 2036-131 322). The continuous outer shield of the semirigid cables interconnects all RF and IF modules.

6. EMI Safety Margin Analysis

EMI safety margin analysis for subassemblies as complex as the FEB are difficult to perform mathematically. The shielding analysis has shown that the pentration into the FEB from the Shuttle radars will be negligible due to the wall thickness of the enclosure. Leakage through the seams of the outer box is minimized through the use of conductive elastomer gaskets. Separate "doghouses" surround the data and power connectors. The data and power lines enter the FEB through RFI feedthroughs. Within the FEB are sysnthesizer sources, whose frequency is offset from the IF passbands. All RF cabling within the FEB is accomplished with semi-rigid continous shield cable. It is our experience that such systems can have minimum spurious response if the connectors are properly tightened. (In most cases, power supply isolation is the more critical item.) In addition, the FEB contains a CMOS computer with a 5 MHz clock. This "baseband" radiation will most adversely affect the low-level filter detector diodes. These diodes are contained in a metal enclosure by the filter manufacturer, and the entire filter is enclosed in an "eggcrate" metal enclosure.

EMI safety margin analysis is usually conducted by assigning a range of numbers (on a logarithmic scale). High power transmitters may have a value of +13 to +9 depending upon the power level and frequency. Sensitive receivers with an input signal level of microwatts would be assigned a number of 0 or 1. Safety margin analysis typically requires that after the shielding effects are included, the attenuated "threat" is well below the "receptor" threshold. The FEB does not contain any exposed antennas. All RF cabling is fully shielded. All low level signal points are metal encased. A detailed numeric calculation would not provide a more realistic description of the expected performance.

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